



## Two years of wind-lidar measurements at an Italian Mediterranean Coastal Site

Gullí, D.; Avolio, E.; Calidonna, C. R.; Lo Feudo, T.; Torcasio, R. C.; Sempreviva, Anna Maria

*Published in:*  
Energy Procedia

*Link to article, DOI:*  
[10.1016/j.egypro.2017.08.194](https://doi.org/10.1016/j.egypro.2017.08.194)

*Publication date:*  
2017

*Document Version*  
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

*Citation (APA):*  
Gullí, D., Avolio, E., Calidonna, C. R., Lo Feudo, T., Torcasio, R. C., & Sempreviva, A. M. (2017). Two years of wind-lidar measurements at an Italian Mediterranean Coastal Site. *Energy Procedia*, 125, 214-220.  
<https://doi.org/10.1016/j.egypro.2017.08.194>

---

### General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

European Geosciences Union General Assembly 2017, EGU  
Division Energy, Resources & Environment, ERE

## Two years of wind-lidar measurements at an Italian Mediterranean Coastal Site

D. Gulli<sup>a</sup>, E. Avolio<sup>a</sup>, C. R. Calidonna<sup>a,\*</sup>, T. Lo Feudo<sup>a</sup>, R. C. Torcasio<sup>a</sup>, A. M. Sempreviva<sup>b,a</sup>

*a* Institute of Atmospheric Sciences and Climate, National Research Council CNR- ISAC, UOS Lamezia Terme, Area Industriale Comp. 15, Lamezia Terme 88046, Italy

*b* Technical University of Denmark, DTU, Wind Energy Department, 4000 Roskilde, Denmark

---

### Abstract

Reliable measurements of vertical profiles of wind speed and direction are needed for testing models and methodologies of use for wind energy assessment. In particular, modelling complex terrain such as coastal areas is challenging due to the coastal discontinuity that is not accurately resolved in mesoscale numerical model. Here, we present a unique database from a coastal site in South Italy (middle of the Mediterranean area) where vertical profiles of wind speed and direction have been collected during a two-year period from a wind-lidar ZEPHIR-300® at a coastal-suburban area. We show an overview analysis on two-year 10-minute averaged wind profiles.

© 2017 The Authors. Published by Elsevier Ltd.

Peer-review under responsibility of the scientific committee of the European Geosciences Union (EGU) General Assembly 2017 – Division Energy, Resources and the Environment (ERE).

**Keywords:** wind-lidar; wind energy; breeze; coastal wind condition

---

### 1. Introduction

Nowadays wind lidar is accepted as standard in wind energy studies. This technology offers a relatively simple plug and play system as an alternative to standard met-mast installation. As it is a relative new technology, long-term databases are missing especially in complex and coastal areas. In particular, coastal areas introduce the

---

\* Corresponding author. Tel.: +39 0968209150; fax: +39 0968209150.

E-mail address: [cr.calidonna@isac.cnr.it](mailto:cr.calidonna@isac.cnr.it)

challenge of the coastal discontinuity, which is often not accurately resolved in mesoscale numerical models. The actual trend in designing more cost-effective and taller turbine with a longer lifetime requires a deep analysis and understanding of the conditions in which a wind power plant will operate over its lifetime.

Developing wind farm projects requires high quality databases under a wide range of atmospheric conditions or high resolution models that could accurately take into account the effect of the sea-land coastal discontinuity.

Wind-lidars in [1,2] have been shown to be functional for studying the evolution of the vertical wind structure coastal atmospheric boundary layer both on- and offshore. Regarding wind energy studies, in [3,4] detailed statistical analysis of Weibull distribution and parameter detection was conducted comparing/integrating wind measurement and forecasts.

Here, we present a unique database from a coastal site in Italy, in the middle of the Mediterranean area where wind speed and direction vertical profiles have been collected during a two-year period from a Wind-lidar ZEPHIR 300® at a coastal suburban area. In a previous paper one-year period was presented giving first results in wind flow evolution of the area [5]. We show an analysis of 10-minute averaged wind profiles over the whole period.

The paper is organised as follows: after this introduction, Section 2 introduces the experimental site and the data set. Section 3 discusses the data analysis and in the final section results and future works are given.

## 2. Experimental site and dataset

### 2.1. Experimental site

The experimental site, the area of the CNR-ISAC section of Lamezia Terme, is located at about 600 m from the coastline in South Italy (Calabria region, Figure 1). Calabria is a mountainous peninsula about 50 km wide and elongated 300 km in the north south direction in the Central Mediterranean. The experimental area is flat and at the end of a west-east oriented valley (the Marcellinara gap) that crosses the peninsula acting as a connecting channel between the Tyrrhenian and Ionian seas and surrounded by mountains up to 1246 m high (Reventino Mount).

This location is a natural laboratory to study land-sea interaction in complex terrain. It is characterized by a synoptic wind mostly from the west and east – west oriented sea/land and mountain/valley breeze systems.

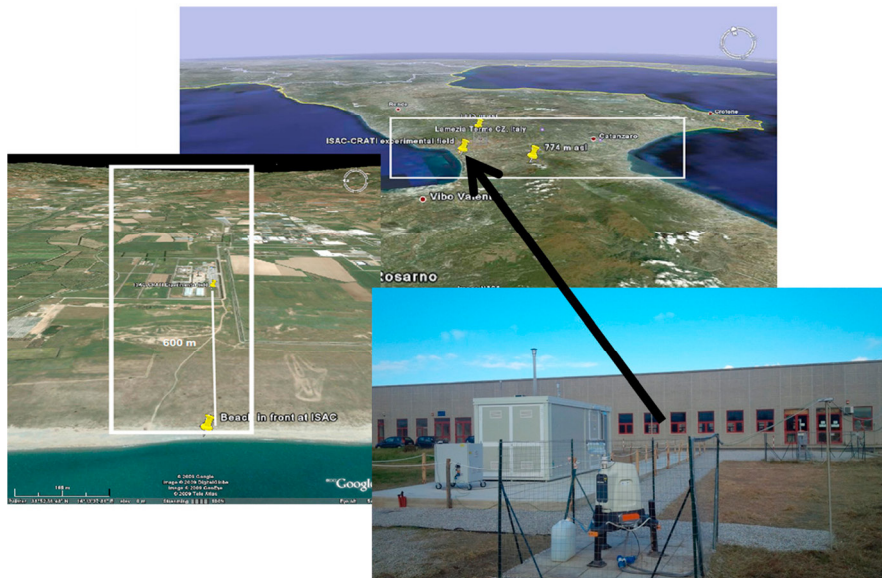


Figure 1 Location and experimental setup of the super site CNR-ISAC GAW-WMO, of Lamezia Terme.

## 2.2. Available Datasets

The wind monitoring activity is performed using the following instruments:

- a meteorological station Metmast Vaisala WTX250 at 10 m,
- a ZephIR 300 wind lidar that provides vertical profiles of U and DIR for 10 levels from 10 to 300 m
- a sonic anemometer operative since April 2017.

Table 1 below shows the instruments and the sampling periods

Table 1 Instrument data set

Instrument	Period	Data type	Time average	Measurements height(s)
Metmast Vaisala WTX250 (cgf 1)	13/06/2013 – 20/11/2014	WS, WD	10 min	8,5 m a.g.l.
Metmast Vaisala WTX250 (cgf 1)	20/11/2014– present	WS, WD	10 min	10 m a.g.l.
Wind Lidar ZephIR 300 (firmware 1.x)	13/07/2013 – present	WS, WD	10 min	10 to 300 m (10 levels).
Wind Lidar ZephIR 300 (firmware 2.x)	2/02/2014 –	WS, WD	10 min	10 to 300 m (10 levels).
Gill Sonic Anemometer	10/04/2017 – present	WS, WD, U,V, W	30 min (20Hz measure)	10 m a.g.l.

In particular, the ZephIR 300 wind lidar from Natural Power is a continuous-wave (CW) lidar system that provides wind measurements across ten user-defined heights (Table 1). ZephIR 300 measures 10-min averaged vertical profiles of wind speed and direction, by combining a series of radial measured wind speed components, from at least three different beam directions, into a three-dimensional wind vector. Different firmware in Table 1 results in a higher data availability for firmware 2 than firmware 1.

Real time data are available at [http://www.i-amica.it/iamica/?page\\_id=1122](http://www.i-amica.it/iamica/?page_id=1122). Table 2 shows the availability of dataset.

Table 2 Wind lidar data set availability

Instrument	Year	Spring	Summer	Fall	Winter
Wind Lidar ZephIR 300 (firmware 1.x)	2013	-	89,5%	89,3%	86,3%
Wind Lidar ZephIR 300 (firmware 2.x)	2014	92,1%	95,8%	89,2%	89,9%
	2015	94,5%	92,4%		

## 3. Data Analysis

In this section, we show a seasonal data analysis in terms of wind roses, wind speed profiles and Weibull distribution.

Considering the complex orography surrounding the experimental site, in Fig 1, a directional analysis is necessary to understand the impact of each orographic feature on the measurements.

Seasonal analysis allows to capture effect of sea land temperature difference on the interplay between synoptic and local flow. Fig. 2 shows the seasonal wind roses over the two-year period, at the different measuring heights from the wind-lidar. The wind roses show three main directions due to the orographic features surrounding the location:

East-west sea-land mountain-valley breeze systems and large-scale flow from the east – north east (mainly during winter), and from the west [6].

During summer, considering JJA months, the synoptic flow blows in the same direction as the sea breeze, and often prevents the land breeze to develop. Wind from east north – east blows mainly during winter, while is almost absent during summer. Comparison during the two different years confirms these seasonal features.

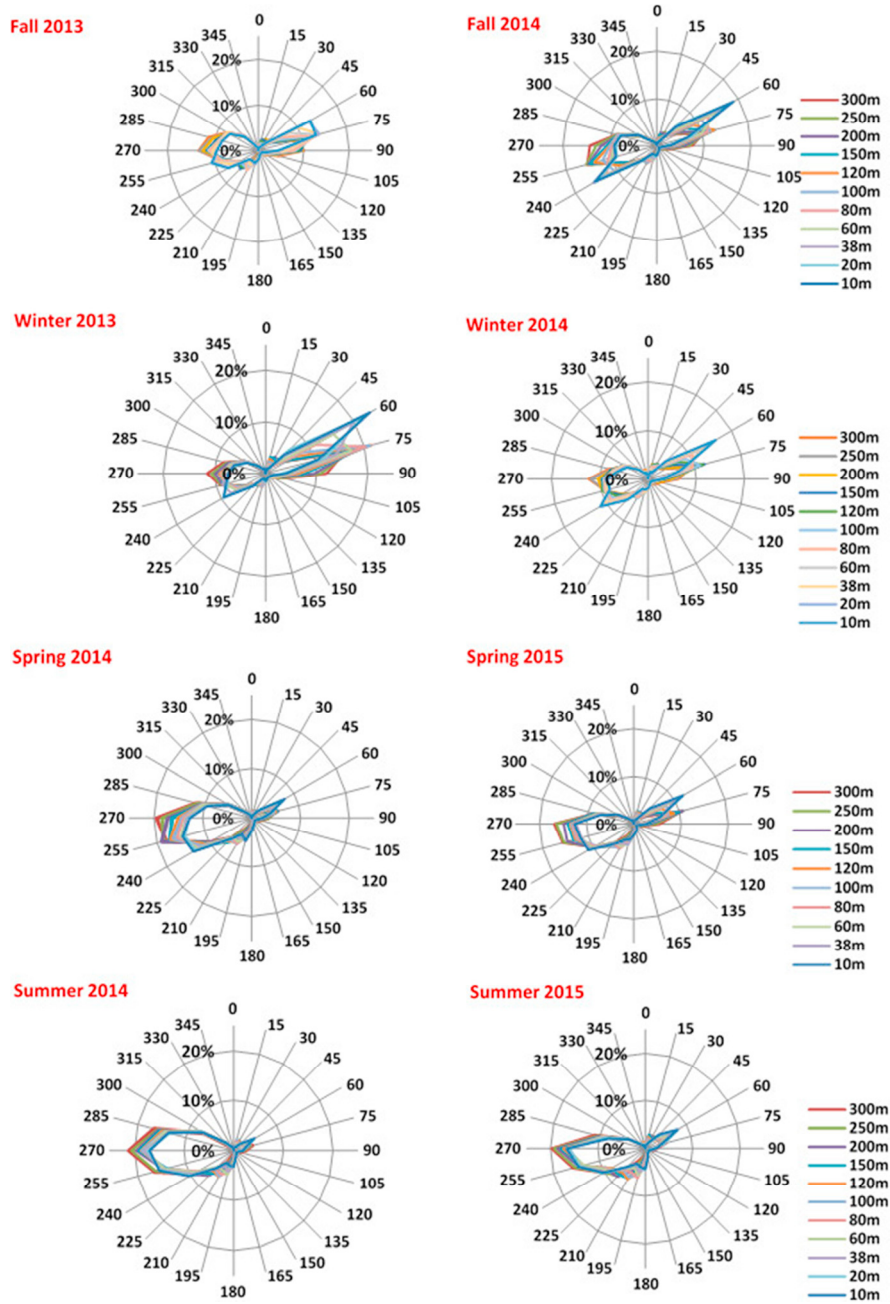


Figure 2 Seasonal wind roses for two one-year period (2013- 2014 left) and (2014-2015 right)

Fig. 3, shows the seasonal mean vertical wind profiles for i) all directions, ii) for offshore flow and iii) for onshore flow, from fall 2013 to summer 2015.

Comparing profiles according to directions we note that:

- For a 30-degree sector centered around 90 degrees (east), offshore wind, the wind profiles indicate an internal layer varying between 80 and 100m, depending on the season; this can be associated to a night stable boundary layer typical for land conditions.
- For a 30-degree sector centred around 270 degrees (west), onshore winds, the profiles show a kink that indicates an Internal Boundary Layer (thermal or neutral) growing from the coast to inland following the sea-land steep change in surface characteristics during i.e. sea breeze cases. Roughness is higher in the lower layer with respect to the upper layer reflecting the values of land and sea roughness respectively.

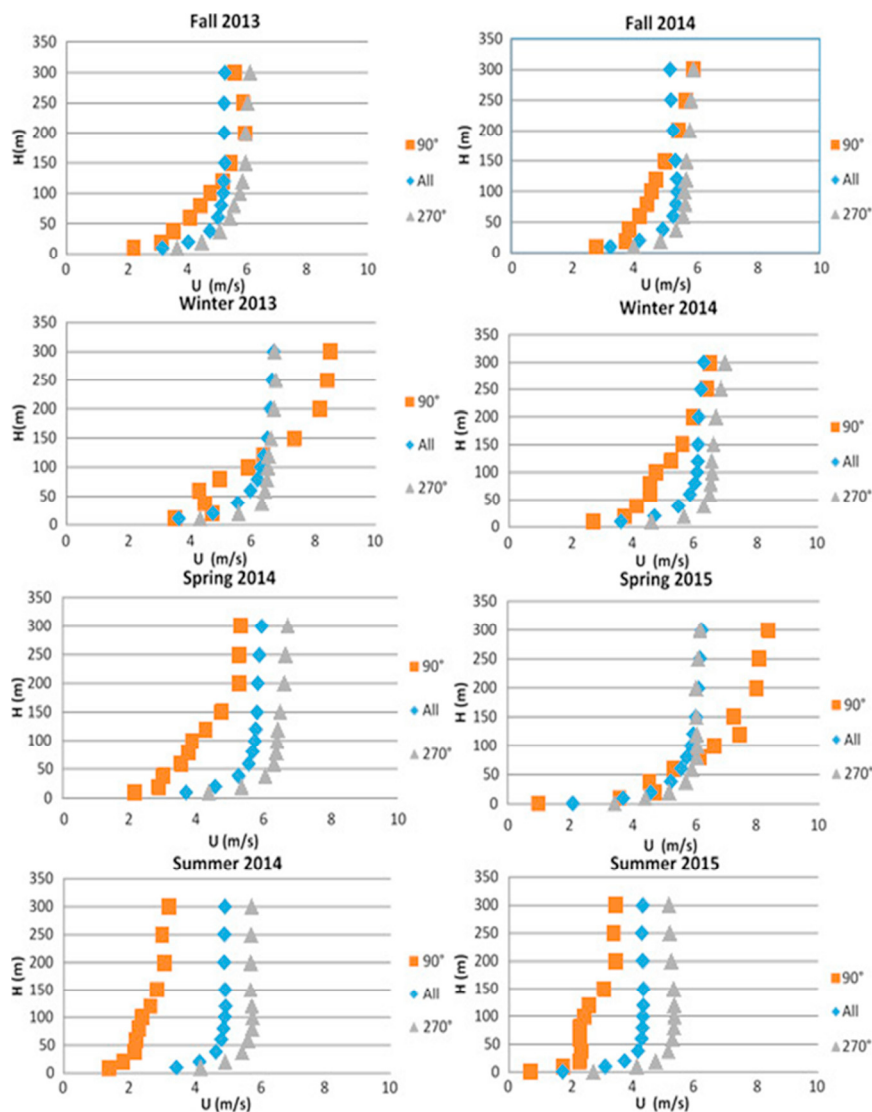


Figure 3 Seasonal wind speed vertical profiles (2013 – 2015) all directions (light blue), offshore (90°) (orange), and onshore (270°) (grey) flows.

Seasonal average vertical wind profiles have similar features in the two different years especially during summer. During spring 2015, we note higher wind and wind variability compared to spring 2014 during offshore flow.

It is also interesting to consider the statistics for mean and standard deviation according to heights, years and directions



As an example, Table 3 shows the different mean wind speed and standard deviations in May 2014 and May 2015.

For the east sector, the wind speed  $U > 10 \text{ m/s}$  from above 100 m in May 2015 is slightly high compared to  $U > 2.52 \text{ m/s}$  during May 2014. In this case, the variability in May 2015 is likely due to i) the occurrence of a strong synoptic eastern flows from the Balkans (some episodes), ii) the occurrence of stable conditions during the night as well as the low occurrence of the wind from the sector. (Fig. 2)

Table 3 Mean and standard deviations of wind speed profiles for all directions and 90 and 270 degree sectors for May 2014 and May 2015

Height	May 2014						May 2015					
	All-data		Sector= 90°		Sector 270°		All-data		Sector= 90°		Sector 270°	
	Mean	St.dev	Mean	St.dev	Mean	St.dev	Mean	St.dev	Mean	St.dev	Mean	St.dev
300	5,56	3,04	5,05	4,45	6,41	2,87	5,27	3,32	9,72	7,29	5,59	
250	5,50	3,04	5,14	4,46	6,35	2,90	5,19	3,31	10,12	7,43	5,61	
200	5,44	3,03	4,55	4,12	6,30	2,92	5,11	3,29	10,67	7,57	5,61	
150	5,41	2,99	3,24	3,14	6,19	2,91	5,05	3,23	10,78	7,39	5,67	
120	5,40	2,94	2,51	1,56	6,09	2,88	4,98	3,19	11,17	6,82	5,64	
100	5,39	2,89	2,52	1,46	6,13	2,86	4,91	3,14	9,78	7,17	5,64	
80	5,36	2,81	2,71	1,34	6,12	2,79	4,84	3,06	8,74	7,00	5,59	
60	5,27	2,69	2,33	1,18	6,08	2,70	4,73	2,93	7,21	6,69	5,45	
38	5,02	2,48	1,91	0,85	5,83	2,53	4,56	2,66	5,77	5,74	5,29	
20	4,39	2,14	1,86	0,88	5,16	2,15	4,12	2,26	6,89	5,07	4,85	
10	3,63	1,81	1,47	0,69	4,28	1,79	3,40	1,87	5,05	3,66	4,23	

Fig. 4 below shows the variation of the fitted Weibull frequency distribution as a function of height for summer 2015 (Top) and winter 2014 (Bottom) for (a) all directions (b) From 90 degrees and (c) from 270 degrees. The Weibull for 90 degrees sector, is characteristics for nighttime stable conditions, (wind from east, high percentage of calms) also enhanced by the presence of buildings.

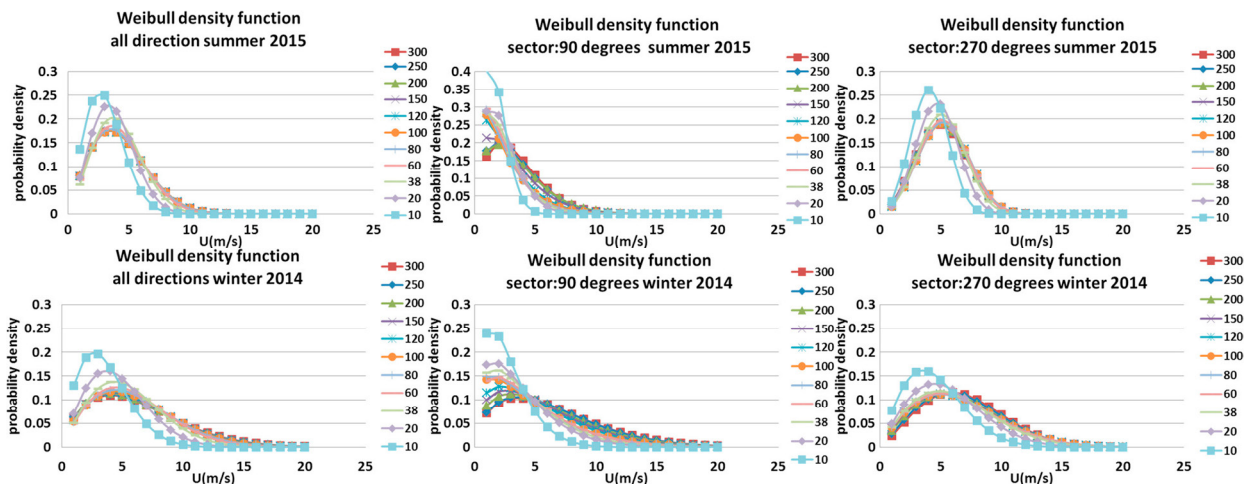


Figure 4 Weibull frequency distribution for height during summer 2015 (Top) and winter 2014 (Bottom) - for all directions, 90 and 270 degrees.

Looking at the change in shape of the Weibull distribution with height, the height of the stable layer during summer and winter seems to be at around 100 m, as seen from the profiles. In fact 100m profile shows less variability of the shape parameter and comparing to wind profiles in Fig. 3 similar averaged wind speed values are

measured comparing seasons between two years. This is also confirmed for the 270 degree sector, the shape is changing with height and the height of 100 m can be seen as the height of the internal boundary layer as from the wind profiles.

#### 4. Final remarks and future work

In this paper, we present results from the analysis of a unique database of vertical profiles of wind speed and directions from a wind lidar ZephIR 300® at 10 levels at a coastal site over a two-year period. We present the general characteristics of the wind flow vertical structure in terms of seasonal mean vertical wind profiles for onshore and offshore flow and how the Weibull distribution changes with height. For both onshore and offshore flows, we note two vertical layers: an inner layer of about 80-100m depth and an outer layer. The internal layer can be ascribed to: (i) the stable SL that develops during the night following the daily cycle of the atmospheric stability, typical over land, for wind coming from east. This condition often causes a decoupling between the stable SL and the wind aloft or to (ii) the height of the internal boundary layer that develops inland from the coastline, for onshore flows e.g. sea breeze.

Work in progress includes detailed analyses to investigate the impact of the building distribution around the site, on the wind profile shape in case of offshore flows. Further studies, including turbulence measures from a sonic anemometer, will allow better characterizing the stability conditions in the surface layer for accurate analyses of the profiles.

#### Acknowledgements

This work was partially supported by project I-AMICA Infrastructure PON03\_00363 Also the work is within the collaboration between DTU and CNR-ISAC in the frame of European Energy Research Alliance, Joint Programme “Wind Energy”, EERA-JPWIND Sub Programme “Wind Conditions”.

#### References

- [1] Lo Feudo, Teresa, Calidonna, Claudia R., Sempreviva, Anna Maria, Courtney, Michael, De Leo, Leonardo, Federico, Stefano, Wagner, Rozanne, Bellecci, Carlo (2010) “Flow evolution at a coastal site in the Central Mediterranean”. Detailed Program (online). ISARS, 2010.
- [2] Wagner, Rozanne, Lo Feudo, Teresa, Courtney, Michael, Calidonna, Claudia R., De Leo, Leonardo, Sempreviva, Anna Maria (2010) .Use of Doppler LIDAR for measuring the vertical profiles of wind speed at a coastal site. Detailed Program (online) ; ISARS, 2010.
- [3] Bolle, HJ (2003). *Mediterranean Climate -Variability and Trends*. Springer- Verlag, Berlin.
- [4] Gryning SE, Batchvarova E, Floors R, Peña A, Brümmner B, Hahmann AN, Mikkelsen T.(2013) “Long-term profiles and Weibull distribution parameters up to 600 meters in a rural coastal and an inland suburban area”. *Boundary-Layer Meteorol.* 2013;150(2):167–184
- [5] Calidonna, Claudia R., Gullì, Daniel, Avolio, Elenio, Federico, Stefano, Lo Feudo, Teresa, Sempreviva, Anna Maria (2015). “One Year of Vertical Wind Profiles Measurements at a Mediterranean Coastal Site of South Italy”. *ERE Procedia* 76, (2015): 121–127 DOI:10.1016/j.egypro.2015.07.871: 2015
- [6] S. Federico, S., Pasqualoni, L. Sempreviva, A.M., De Leo, L., Avolio, E., Calidonna, C.R., Bellecci, C. (2010) “The seasonal characteristics of the breeze circulation at a coastal Mediterranean site in South Italy”, *Adv. Sci. Res.* 4, (2010): 47-56, doi:10.5194/asr-4-47-2010